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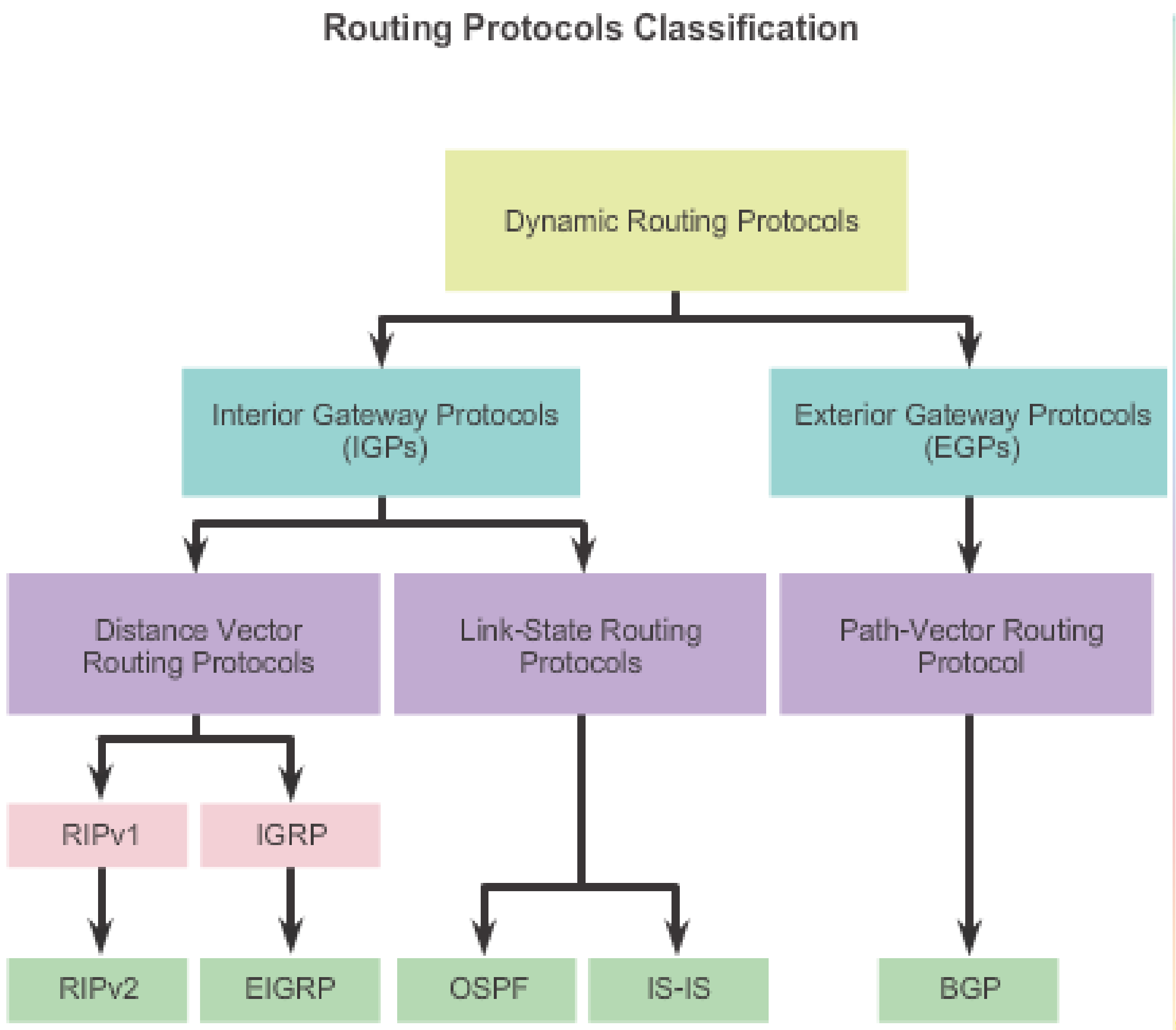
CHAPTER 4: ROUTING DYNAMIC

Routing & Switching

CHAPTER4

ROUTING ?

CLASSIFYING ROUTING PROTOCOLS



THE EVOLUTION OF DYNAMIC ROUTING PROTOCOLS

- Dynamic routing protocols used in networks since the late 1980s
- Newer versions support the communication based on IPv6

Routing Protocols Classification

	Interior Gateway Protocols				Exterior Gateway Protocols
	Distance Vector		Link-State		Path Vector
IPv4	RIPv2	EIGRP	OSPFv2	IS-IS	BGP-4
IPv6	RIPng	EIGRP for IPv6	OSPFv3	IS-IS for IPv6	BGP-MP

Purpose of Dynamic Routing Protocols ?

PURPOSE OF DYNAMIC ROUTING PROTOCOLS

Routing Protocols are used to facilitate the exchange of routing information between routers.

The purpose of dynamic routing protocols includes:

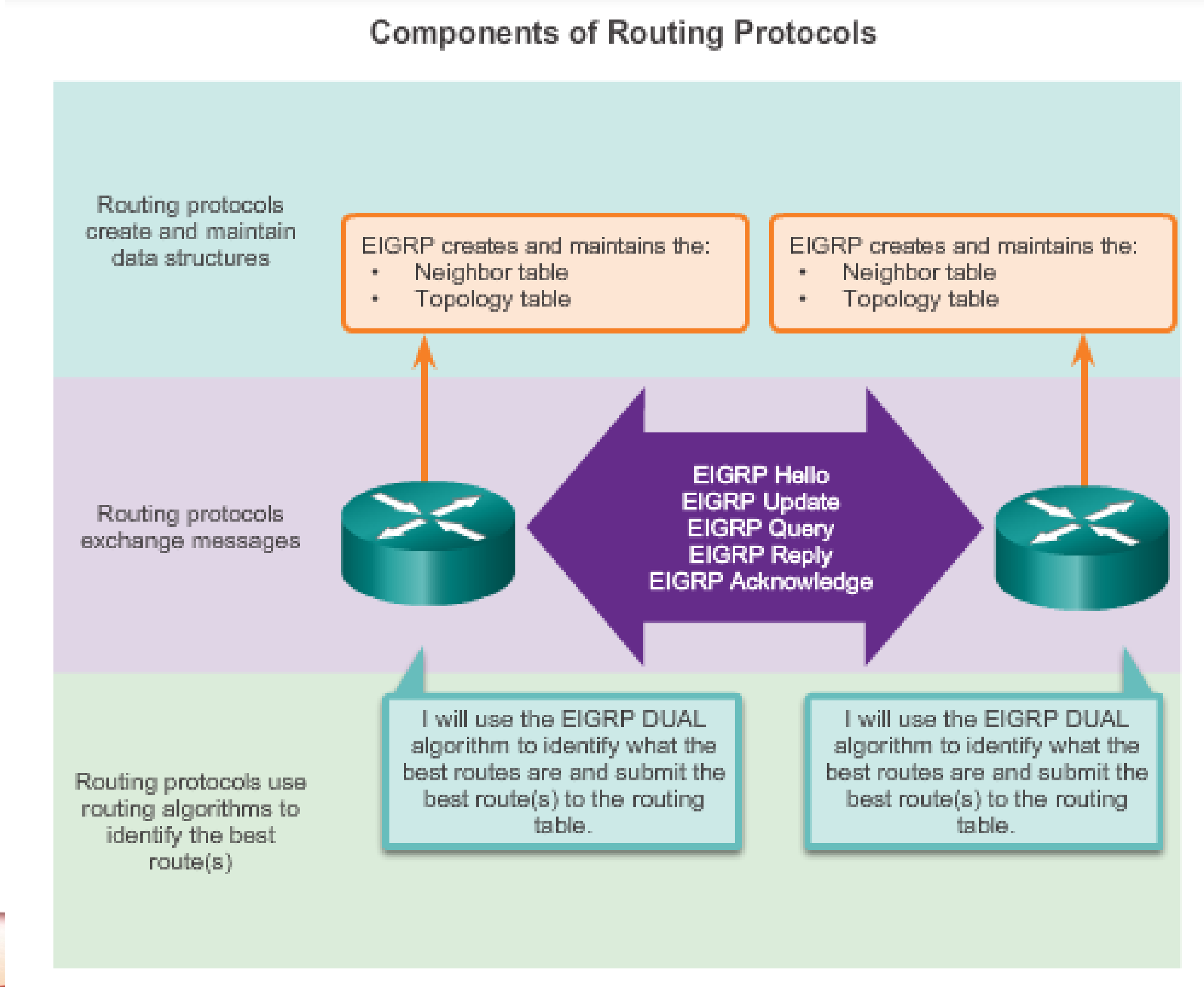
- Discovery of remote networks
- Maintaining up-to-date routing information
- Choosing the best path to destination networks
- Ability to find a new best path if the current path is no longer available

PURPOSE OF DYNAMIC ROUTING PROTOCOLS (CONT.)

Main components of dynamic routing protocols include:

- **Data structures -** Routing protocols typically use tables or databases for its operations. This information is kept in RAM.
- **Routing protocol messages -** Routing protocols use various types of messages to discover neighboring routers, exchange routing information, and other tasks to learn and maintain accurate information about the network.
- **Algorithm -** Routing protocols use algorithms for facilitating routing information for best path determination.

PURPOSE OF DYNAMIC ROUTING PROTOCOLS (CONT.)



Advantages and Disadvantages of dynamic routing ?

The Role of Dynamic Routing Protocols

Advantages of dynamic routing include:

- Automatically share information about remote networks
- Determine the best path to each network and add this information to their routing tables
- Compared to static routing, dynamic routing protocols require less administrative overhead
- Help the network administrator manage the time-consuming process of configuring and maintaining static routes

Disadvantages of dynamic routing include:

- Part of a router's resources are dedicated for protocol operation, including CPU time and network link bandwidth
- Times when static routing is more appropriate

Dynamic verses Static Routing

DYNAMIC VERSES STATIC ROUTING

USING STATIC ROUTING

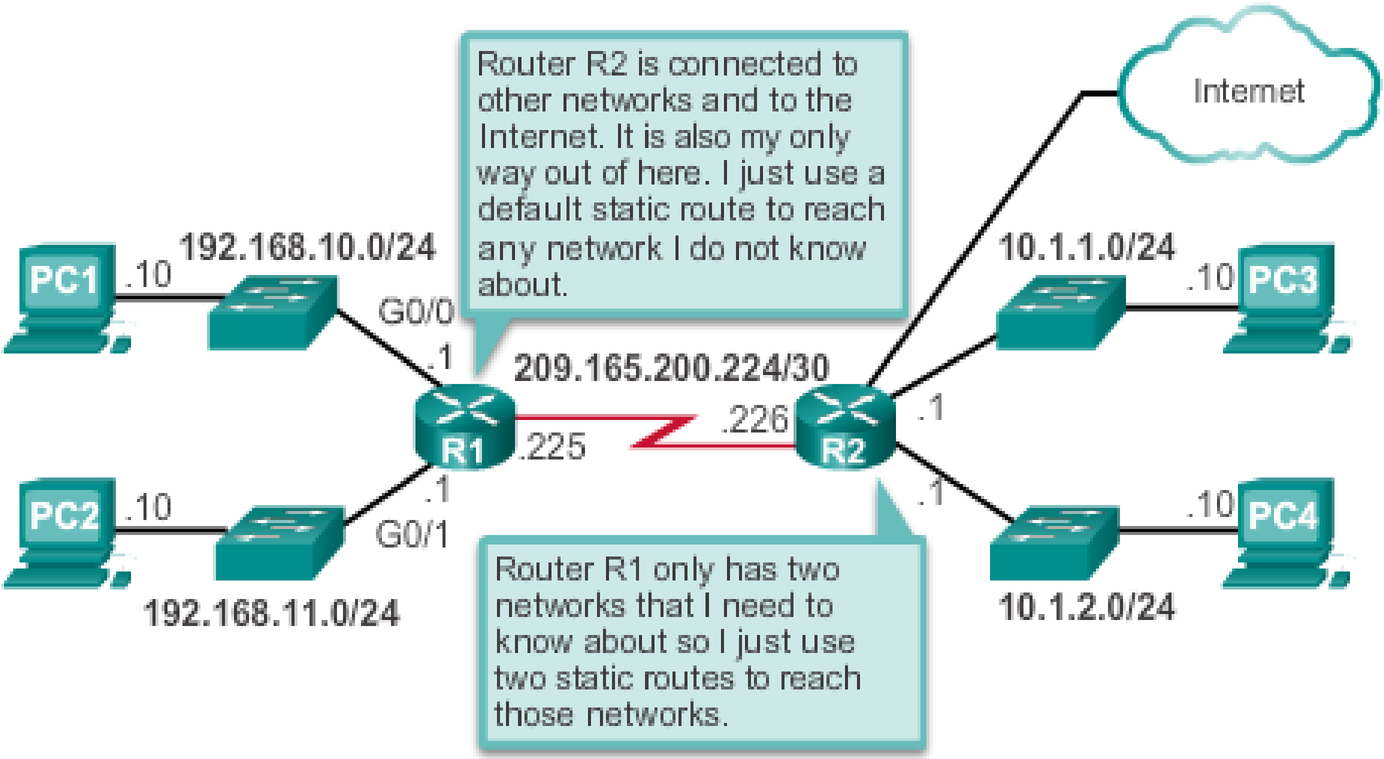
Networks typically use a combination of both static and dynamic routing.

Static routing has several primary uses:

- Providing ease of routing table maintenance in smaller networks that are not expected to grow significantly.
- Routing to and from a stub network. A network with only one default route out and no knowledge of any remote networks.
- Accessing a single default router. This is used to represent a path to any network that does not have a match in the routing table.

DYNAMIC VERSES STATIC ROUTING

USING STATIC ROUTING (CONT.)



DYNAMIC VERSES STATIC ROUTING

STATIC ROUTING SCORECARD

Static Routing Advantages and Disadvantages

Advantages	Disadvantages
Easy to implement in a small network.	Suitable only for simple topologies or for special purposes such as a default static route. Configuration complexity increases dramatically as network grows.
Very secure. No advertisements are sent as compared to dynamic routing protocols.	
Route to destination is always the same.	Manual intervention required to re-route traffic.
No routing algorithm or update mechanism required; therefore, extra resources (CPU or RAM) are not required.	

DYNAMIC VERSES STATIC ROUTING

DYNAMIC ROUTING SCORECARD

Dynamic Routing Advantages and Disadvantages

Advantages	Disadvantages
Suitable in all topologies where multiple routers are required.	Can be more complex to implement.
Generally independent of the network size.	Less secure. Additional configuration settings are required to secure.
Automatically adapts topology to reroute traffic if possible.	Route depends on the current topology.
	Requires additional CPU, RAM, and link bandwidth.

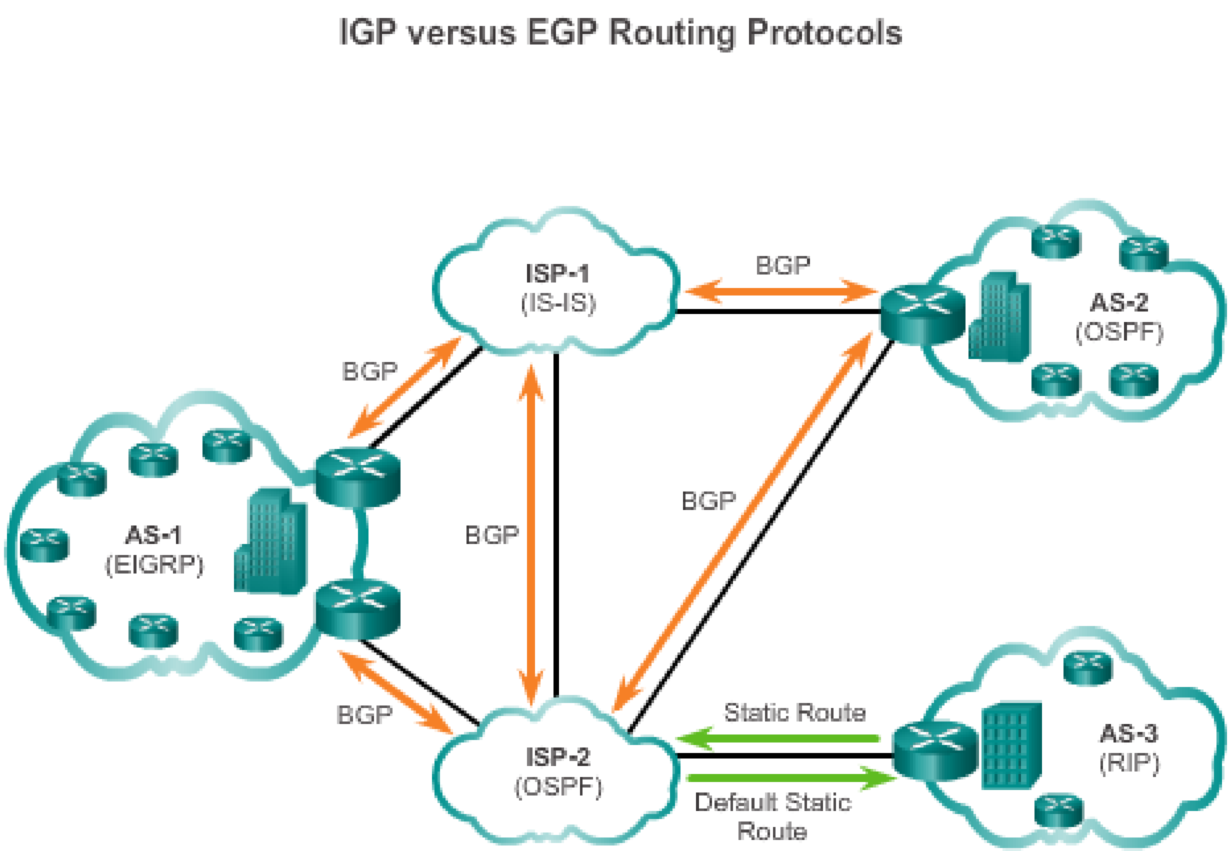
ROUTING PROTOCOL OPERATING FUNDAMENTALS
ACHIEVING CONVERGENCE

The network is converged when all routers have complete and accurate information about the entire network:

- Convergence time is the time it takes routers to share information, calculate best paths, and update their routing tables.
- A network is not completely operable until the network has converged.
- Convergence properties include the speed of propagation of routing information and the calculation of optimal paths. The speed of propagation refers to the amount of time it takes for routers within the network to forward routing information.
- Generally, older protocols, such as RIP, are slow to converge, whereas modern protocols, such as EIGRP and OSPF, converge more quickly.

TYPES OF ROUTING PROTOCOLS

IGP AND EGP ROUTING PROTOCOLS



Interior Gateway Protocols (IGP) -

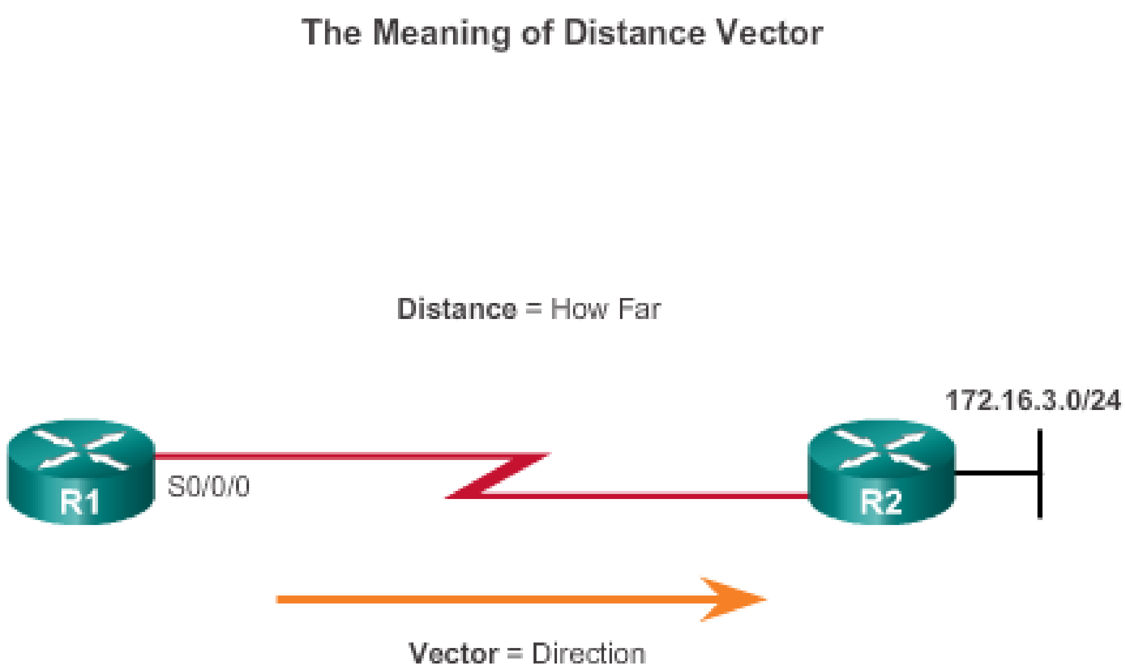
- Used for routing within an AS
- Include RIP, EIGRP, OSPF, and IS-IS

Exterior Gateway Protocols (EGP) -

- Used for routing between AS
- Official routing protocol used by the Internet

TYPES OF ROUTING PROTOCOLS

DISTANCE VECTOR ROUTING PROTOCOLS



For R1, 172.16.3.0/24 is one hop away (distance). It can be reached through R2 (vector).

Distance vector IPv4 IGPs:

- **RIPv1** - First generation legacy protocol
- **RIPv2** - Simple distance vector routing protocol
- **IGRP** - First generation Cisco proprietary protocol (obsolete)
- **EIGRP** - Advanced version of distance vector routing

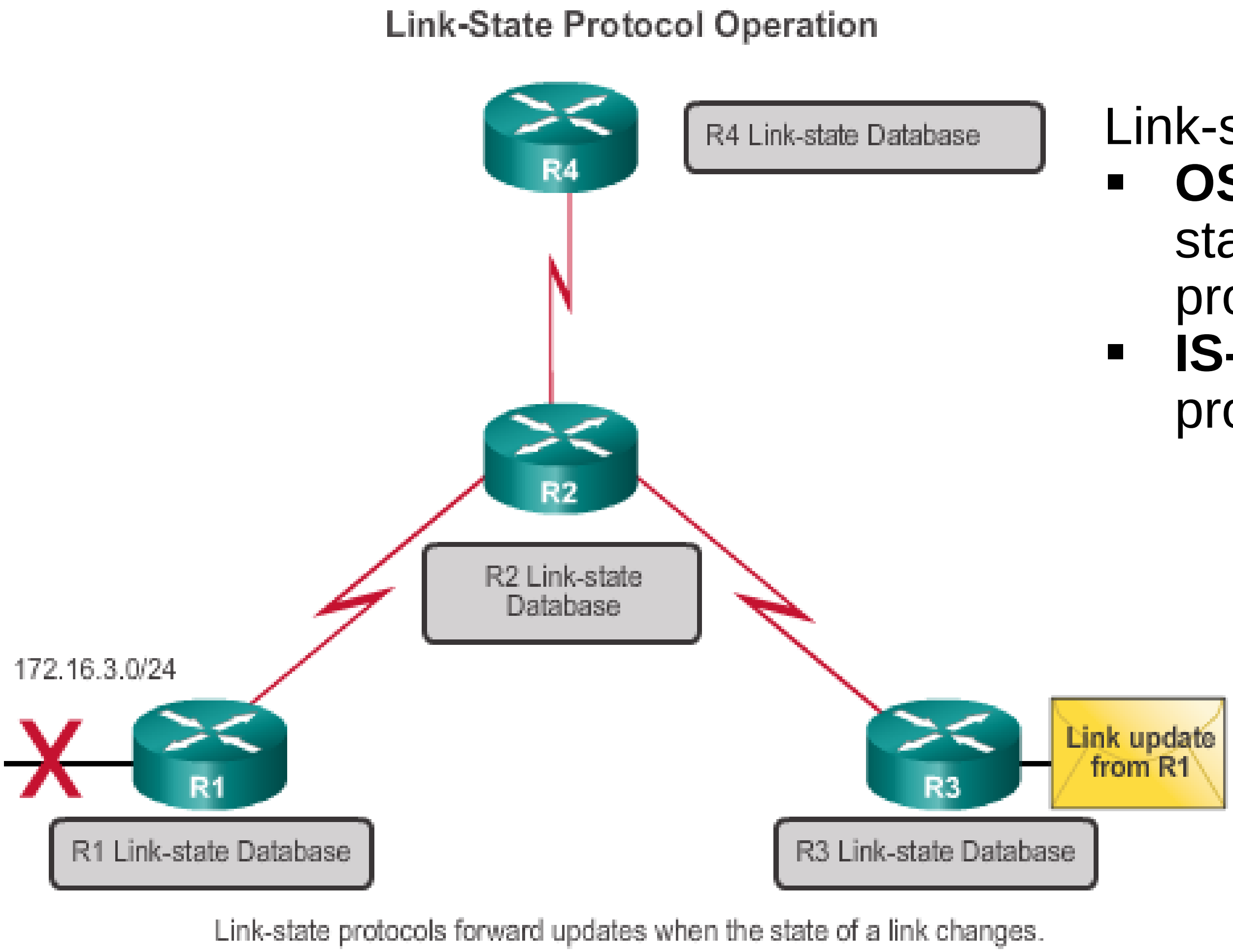
TYPES OF ROUTING PROTOCOLS
DISTANCE VECTOR OR LINK-STATE ROUTING PROTOCOLS

Distance vector protocols use routers as sign posts along the path to the final destination.

A link-state routing protocol is like having a complete map of the network topology. The sign posts along the way from source to destination are not necessary, because all link-state routers are using an identical map of the network. A link-state router uses the link-state information to create a topology map and to select the best path to all destination networks in the topology.

Types of Routing Protocols

Link-State Routing Protocols



Link-state IPv4 IGPs:

- **OSPF** - Popular standards based routing protocol
- **IS-IS** - Popular in provider networks.

CLASSFUL ROUTING PROTOCOLS

Classful routing protocols do not send subnet mask information in their routing updates:

- Only RIPv1 and IGRP are classful.
- Created when network addresses were allocated based on classes (class A, B, or C).
- Cannot provide variable length subnet masks (VLSMs) and classless interdomain routing (CIDR).
- Create problems in discontiguous networks.

TYPES OF ROUTING PROTOCOLS
CLASSLESS ROUTING PROTOCOLS

Classless routing protocols include subnet mask information in the routing updates:

- RIPv2, EIGRP, OSPF, and IS_IS
- Support VLSM and CIDR
- IPv6 routing protocols

TYPES OF ROUTING PROTOCOLS

ROUTING PROTOCOL CHARACTERISTICS

	Distance Vector				Link State	
	RIPv1	RIPv2	IGRP	EIGRP	OSPF	IS-IS
Speed Convergence	Slow	Slow	Slow	Fast	Fast	Fast
Scalability - Size of Network	Small	Small	Small	Large	Large	Large
Use of VLSM	No	Yes	No	Yes	Yes	Yes
Resource Usage	Low	Low	Low	Medium	High	High
Implemenation and Maintenance	Simple	Simple	Simple	Complex	Complex	Complex

ROUTING PROTOCOL METRICS

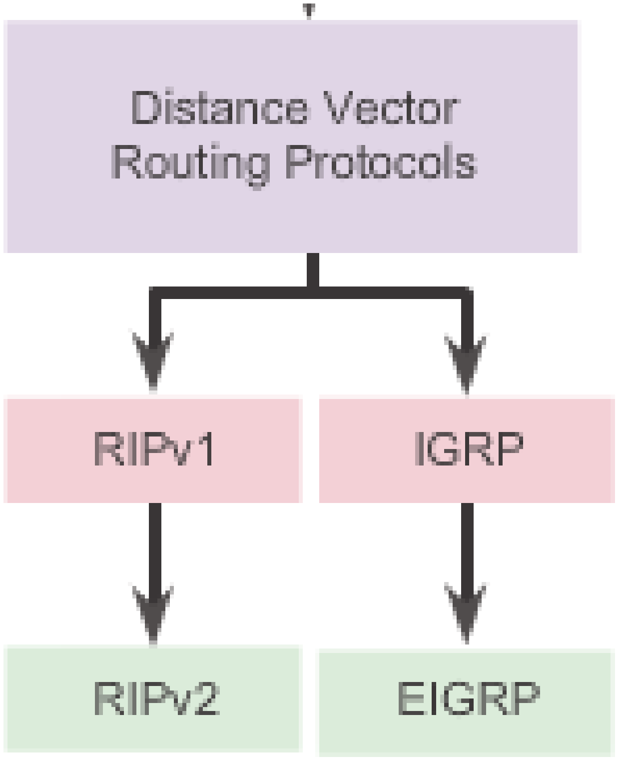
A metric is a measurable value that is assigned by the routing protocol to different routes based on the usefulness of that route:

- Used to determine the overall “cost” of a path from source to destination.
- Routing protocols determine the best path based on the route with the lowest cost.

DISTANCE VECTOR TECHNOLOGIES

Distance vector routing protocols:

- Share updates between neighbors
- Not aware of the network topology
- Some send periodic updates to broadcast IP 255.255.255.255 even if topology has not changed
- Updates consume bandwidth and network device CPU resources
- RIPv2 and EIGRP use multicast addresses
- EIGRP will only send an update when topology has changed



DISTANCE VECTOR ROUTING PROTOCOL OPERATION

DISTANCE VECTOR ALGORITHM

Purpose of Routing Algorithms

- Sending and receiving updates
- Calculate best path and install route
- Detect and react to topology changes

RIP uses the Bellman-Ford algorithm as its routing algorithm.

IGRP and EIGRP use the Diffusing Update Algorithm (DUAL) routing algorithm developed by Cisco.

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TYPES OF DISTANCE VECTOR ROUTING PROTOCOLS

ROUTING INFORMATION PROTOCOL

RIPv1 versus RIPv2

Characteristics and Features	RIPv1	RIPv2
Metric	Both use hop count as a simple metric. The maximum number of hops is 15.	
Updates Forwarded to Address	255.255.255.255	224.0.0.9
Supports VLSM	✗	✓
Supports CIDR	✗	✓
Supports Summarization	✗	✓
Supports Authentication	✗	✓

Routing updates broadcasted every 30 seconds

Updates use UDP port 520

RIPng is based on RIPv2 with a 15 hop limitation and the administrative distance of 120

ENHANCED INTERIOR-GATEWAY ROUTING PROTOCOL

IGRP versus EIGRP

Characteristics and Features	IGRP	EIGRP
Metric	Both use a composite metric consisting of bandwidth and delay. Reliability and load can also be included in the metric calculation.	
Updates Forwarded to Address	255.255.255.255	224.0.0.10
Supports VLSM	✗	✓
Supports CIDR	✗	✓
Supports Summarization	✗	✓
Supports Authentication	✗	✓

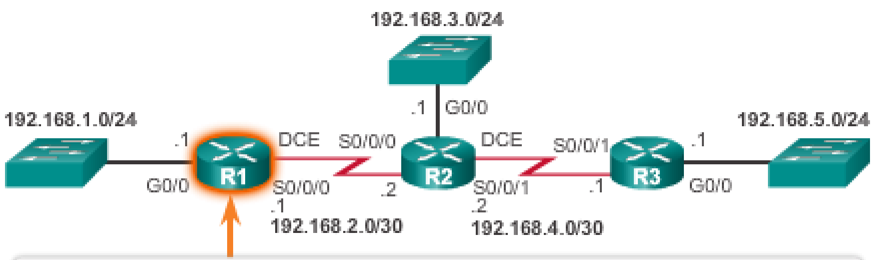
EIGRP:

- Is bounded triggered updates
- Uses a Hello keepalives mechanism
- Maintains a topology table
- Supports rapid convergence
- Is a multiple network layer protocol support

ROUTER RIP CONFIGURATION MODE ADVERTISING NETWORKS

```
R1# conf t
Enter configuration commands, one per line.  End with CNTL/Z.
R1(config)# router rip
R1(config-router)#
```

Advertising the R1 Networks




```
R1(config)#router rip
R1(config-router)#network 192.168.1.0
R1(config-router)#network 192.168.2.0
R1(config-router)#
```

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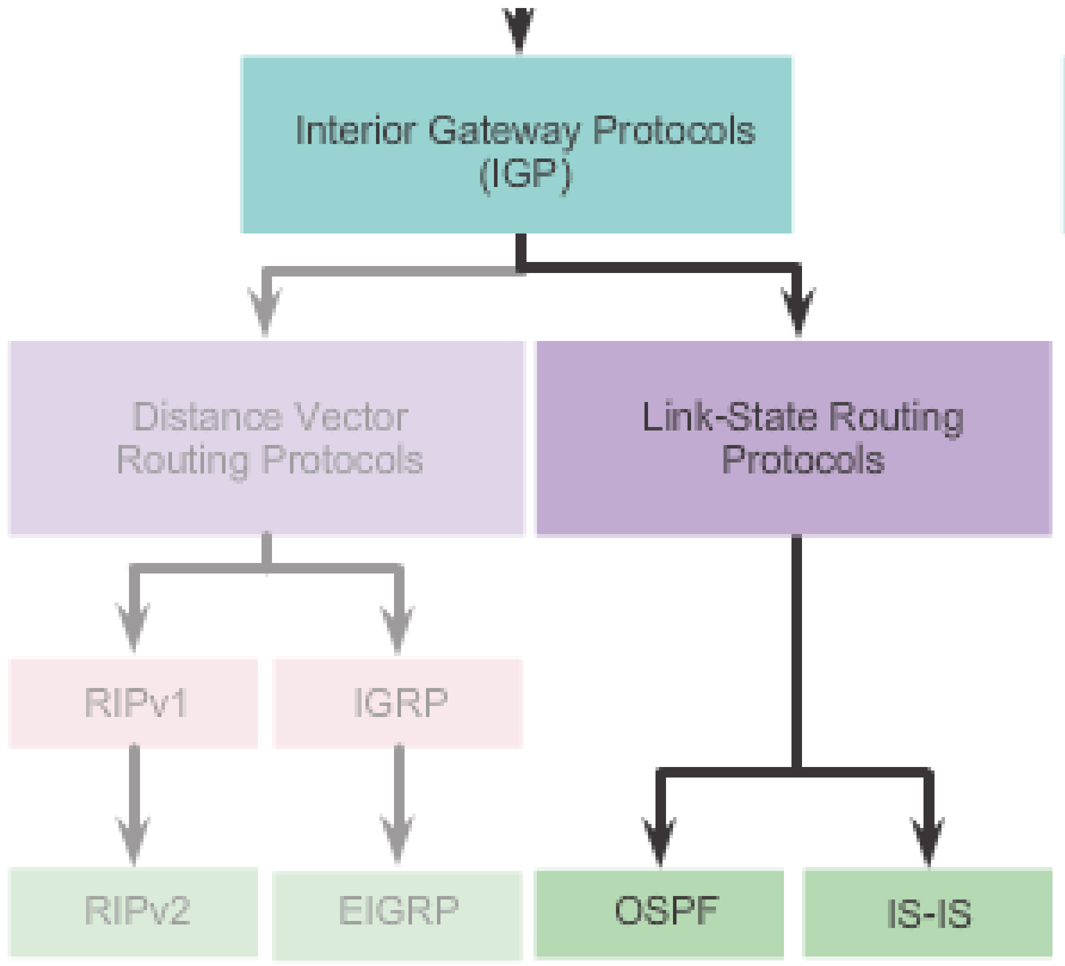
LINK-STATE ROUTING PROTOCOL OPERATION

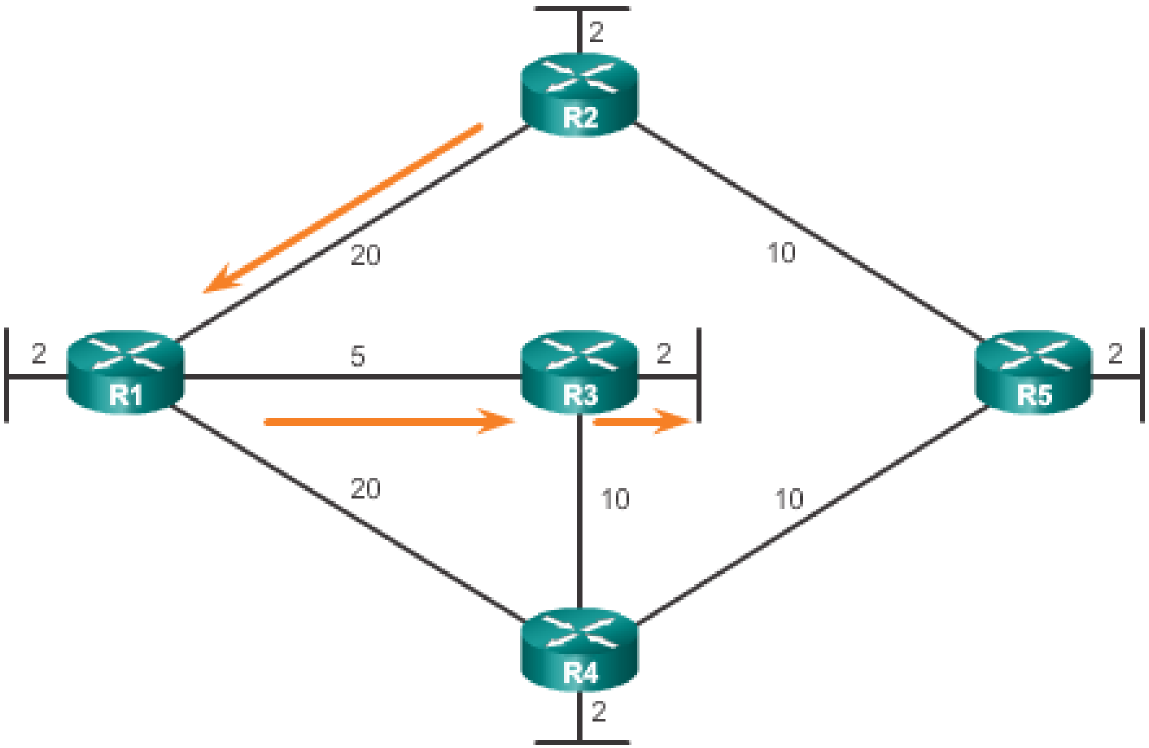
SHORTEST PATH FIRST PROTOCOLS



LINK-STATE ROUTING PROTOCOL OPERATION
DIJKSTRA'S ALGORITHM

Dijkstra's Shortest Path First Algorithm

Shortest Path for host on R2 LAN to reach host on R3 LAN:
R2 to R1 (20) + R1 to R3 (5) + R3 to LAN (2) = 27



LINK-STATE UPDATES

LINK-STATE ROUTING PROCESS

Link-State Routing Process

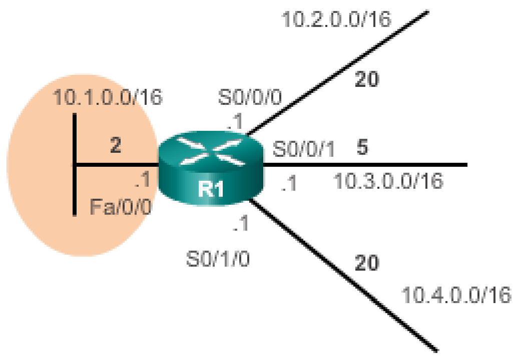
- Each router learns about each of its own directly connected networks.
- Each router is responsible for "saying hello" to its neighbors on directly connected networks.
- Each router builds a Link State Packet (LSP) containing the state of each directly connected link.
- Each router floods the LSP to all neighbors who then store all LSP's received in a database.
- Each router uses the database to construct a complete map of the topology and computers the best path to each destination networks.

LINK-STATE UPDATES

LINK AND LINK-STATE

The first step in the link-state routing process is that each router learns about its own links and its own directly connected networks.

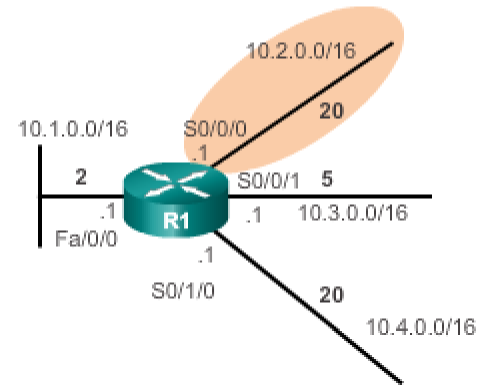
Link-State of Interface Fa0/0



Link 1

- Network: **10.1.0.0/16**
- IP address: **10.1.0.1**
- Type of network: **Ethernet**
- Cost of that link: **2**
- Neighbors: **None**

Link-State of Interface S0/0/0

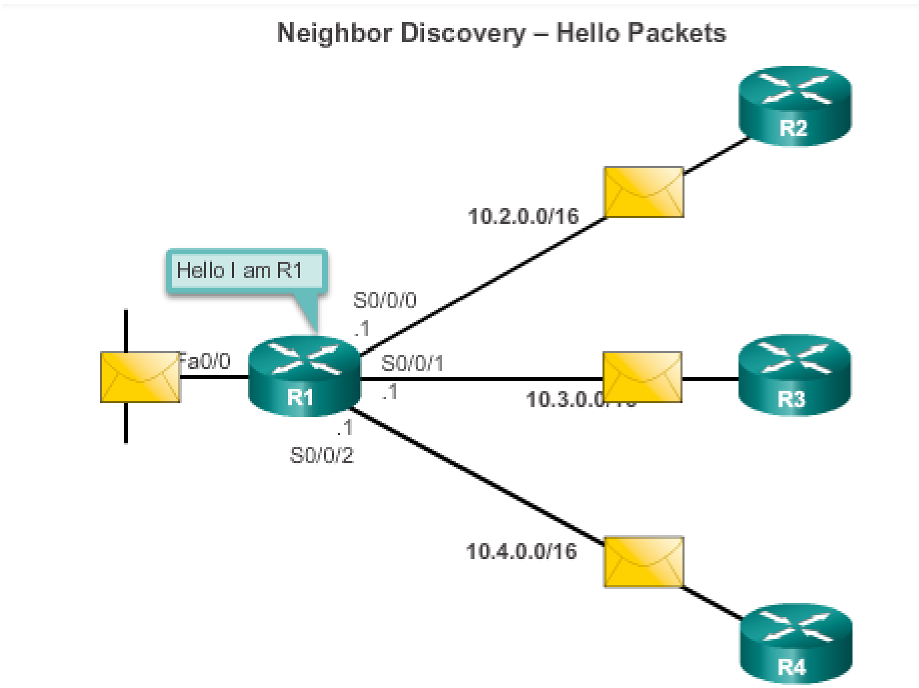


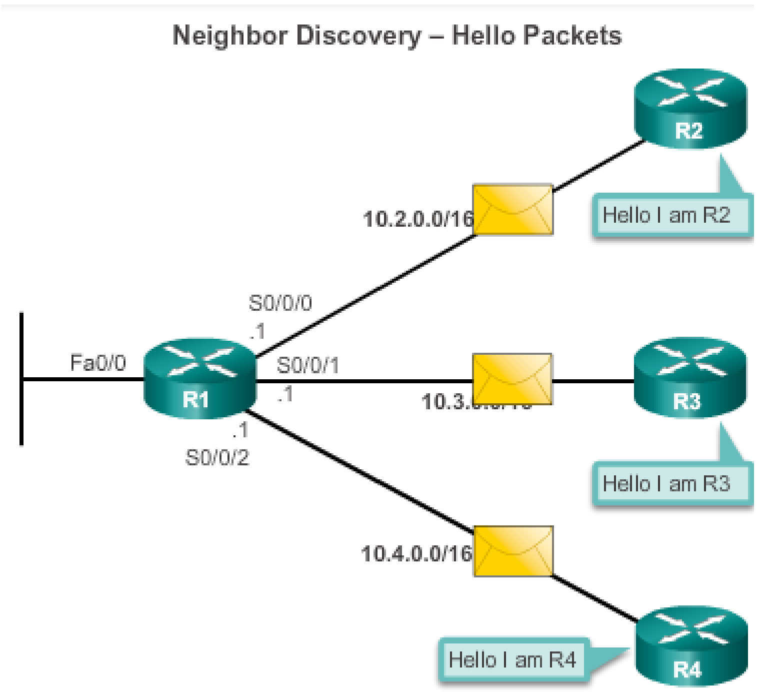
Link 2

- Network: **10.2.0.0/16**
- IP address: **10.2.0.1**
- Type of network: **Serial**
- Cost of that link: **20**
- Neighbors: **R2**

LINK-STATE UPDATES
SAY HELLO

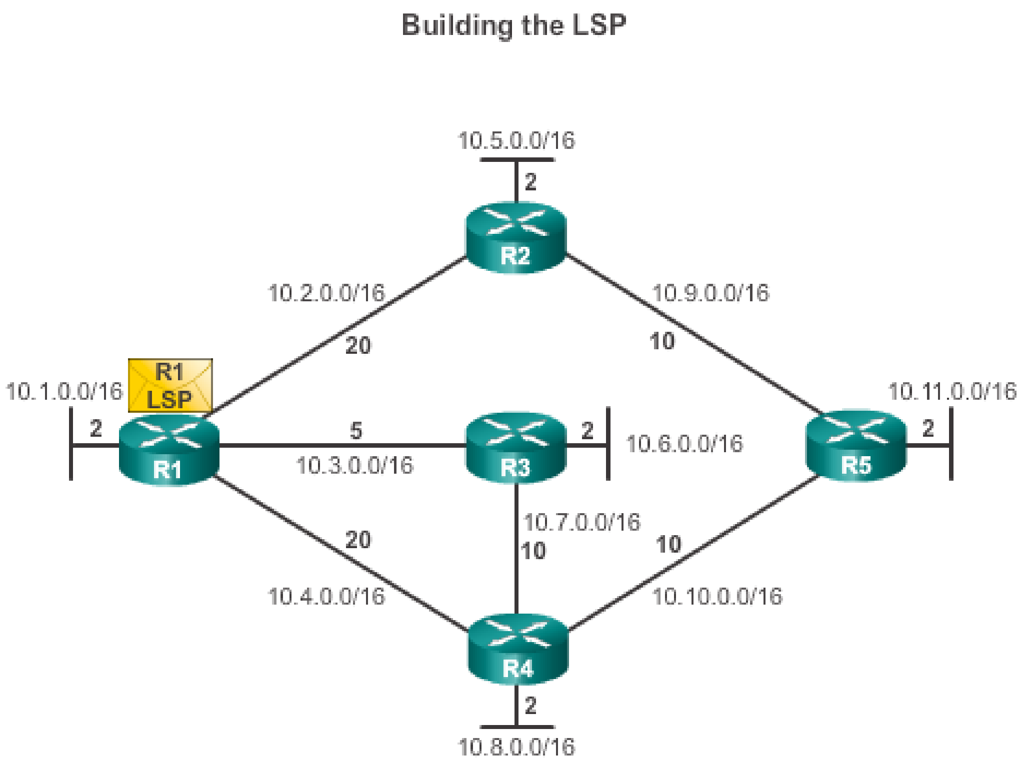
The second step in the link-state routing process is that each router is responsible for meeting its neighbors on directly connected networks.





SAY HELLO

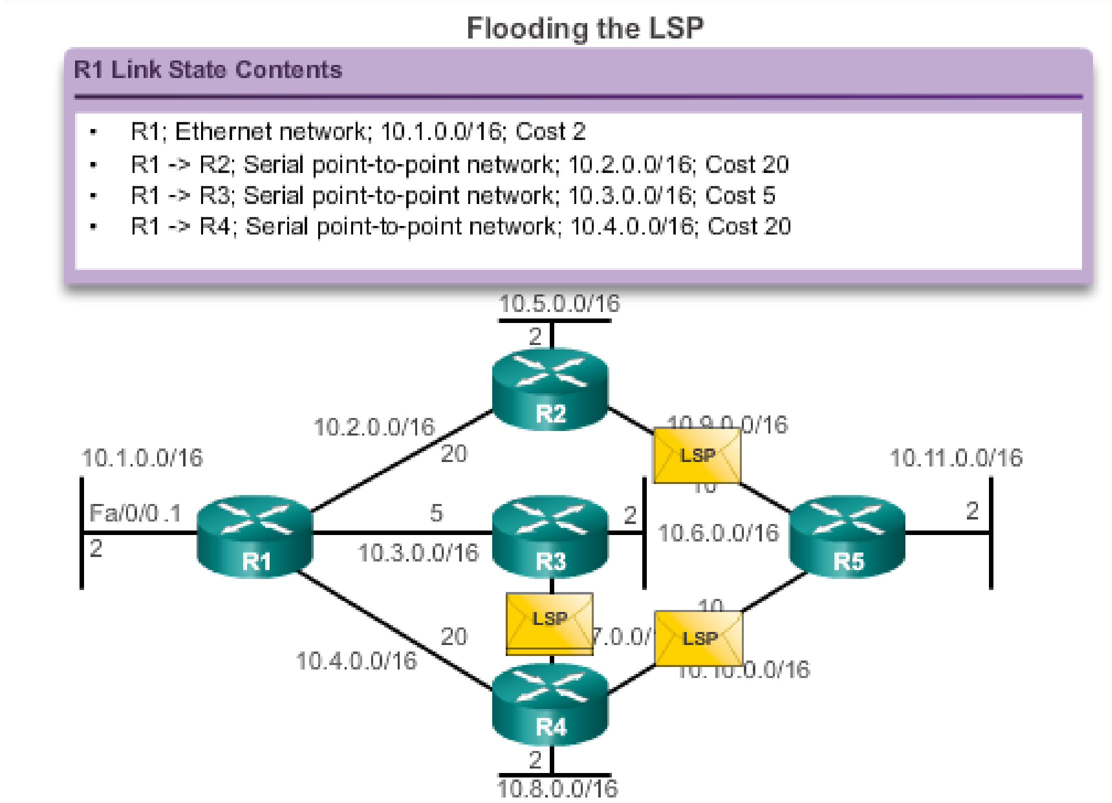
The third step in the link-state routing process is that each router builds a link-state packet (LSP) containing the state of each directly connected link.



1. R1; Ethernet network 10.1.0.0/16; Cost 2
2. R1 -> R2; Serial point-to-point network; 10.2.0.0/16; Cost 20
3. R1 -> R3; Serial point-to-point network; 10.7.0.0/16; Cost 5
4. R1 -> R4; Serial point-to-point network; 10.4.0.0/16; Cost 20

LINK-STATE UPDATES
FLOODING THE LSP

The fourth step in the link-state routing process is that each router floods the LSP to all neighbors, who then store all LSPs received in a database.



LINK-STATE UPDATES

BUILDING THE LINK-STATE DATABASE

The final step in the link-state routing process is that each router uses the database to construct a complete map of the topology and computes the best path to each destination network.

Contents of the Link-State Database

R1 Link-State Database

R1 Link-states:
- Connected to network 10.1.0.0/16, cost = 2
- Connected to R2 on network 10.2.0.0/16, cost = 20
- Connected to R3 on network 10.3.0.0/16, cost = 5
- Connected to R4 on network 10.4.0.0/16, cost = 20

R2 Link-states:
- Connected to network 10.5.0.0/16, cost = 2
- Connected to R1 on network 10.2.0.0/16, cost = 20
- Connected to R5 on network 10.9.0.0/16, cost = 10

R3 Link-states:
- Connected to network 10.6.0.0/16, cost = 2
- Connected to R1 on network 10.3.0.0/16, cost = 5
- Connected to R4 on network 10.7.0.0/16, cost = 10

R4 Link-states:
- Connected to network 10.8.0.0/16, cost = 2
- Connected to R1 on network 10.4.0.0/16, cost = 20
- Connected to R3 on network 10.7.0.0/16, cost = 10
- Connected to R5 on network 10.10.0.0/16, cost = 10

R5 Link-states:
- Connected to network 10.11.0.0/16, cost = 2
- Connected to R2 on network 10.9.0.0/16, cost = 10
- Connected to R4 on network 10.10.0.0/16, cost = 10

LINK-STATE UPDATES
BUILDING THE SPF TREE

Identify the Directly Connected Networks

R1 Link-State Database

R1 Link-states:
- Connected to network 10.1.0.0/16, cost = 2
- Connected to R2 on network 10.2.0.0/16, cost = 20
- Connected to R3 on network 10.3.0.0/16, cost = 5
- Connected to R4 on network 10.4.0.0/16, cost = 20

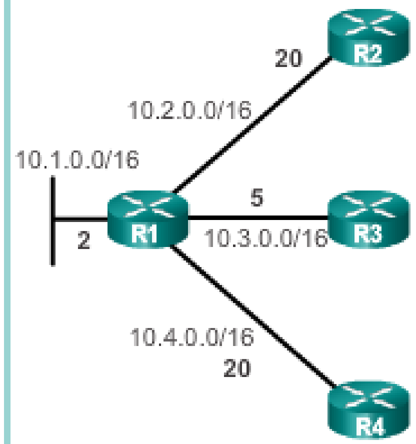
R2 Link-states:
- Connected to network 10.5.0.0/16, cost = 2
- Connected to R1 on network 10.2.0.0/16, cost = 20
- Connected to R5 on network 10.9.0.0/16, cost = 10

R3 Link-states:
- Connected to network 10.6.0.0/16, cost = 2
- Connected to R1 on network 10.3.0.0/16, cost = 5
- Connected to R4 on network 10.7.0.0/16, cost = 10

R4 Link-states:
- Connected to network 10.8.0.0/16, cost = 2
- Connected to R1 on network 10.4.0.0/16, cost = 20
- Connected to R3 on network 10.7.0.0/16, cost = 10
- Connected to R5 on network 10.10.0.0/16, cost = 10

R5 Link-states:
- Connected to network 10.11.0.0/16, cost = 2
- Connected to R2 on network 10.9.0.0/16, cost = 10
- Connected to R4 on network 10.10.0.0/16, cost = 10

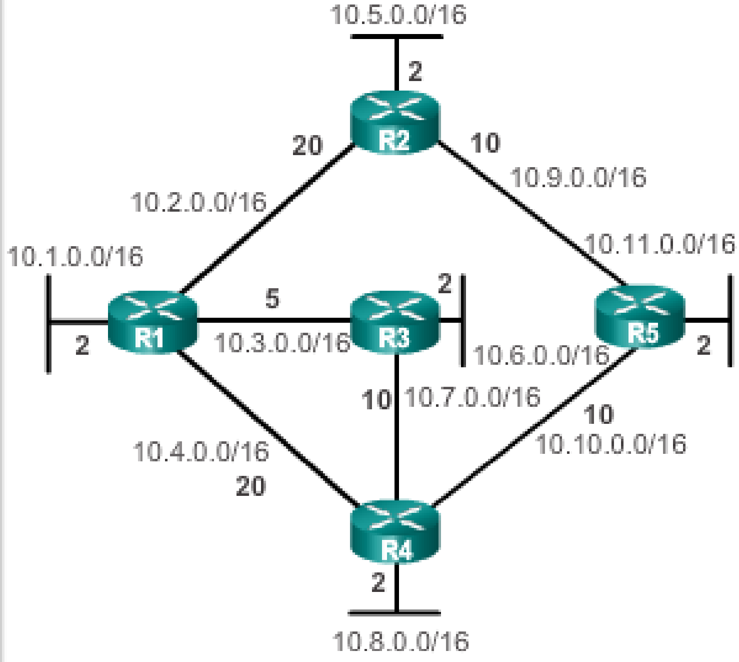
SPF Tree



BUILDING THE SPF TREE

Resulting SPF Tree of R1

Destination	Shortest Path	Cost
10.5.0.0/16	R1 → R2	22
10.6.0.0/16	R1 → R3	7
10.7.0.0/16	R1 → R3	15
10.8.0.0/16	R1 → R3 → R4	17
10.9.0.0/16	R1 → R2	30
10.10.0.0/16	R1 → R3 → R4	25
10.11.0.0/16	R1 → R3→ R4→ R5	27



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LINK-STATE UPDATES

ADDING OSPF ROUTES TO THE ROUTING TABLE

Populate the Routing Table

Destination	Shortest Path	Cost
10.5.0.0/16	R1 → R2	22
10.6.0.0/16	R1 → R3	7
10.7.0.0/16	R1 → R3	15
10.8.0.0/16	R1 → R3 → R4	17
10.9.0.0/16	R1 → R2	30
10.10.0.0/16	R1 → R3 → R4	25
10.11.0.0/16	R1 → R3 → R4 → R5	27

R1 Routing Table

Directly Connected Networks

- 10.1.0.0/16 Directly Connected Network
- 10.2.0.0/16 Directly Connected Network
- 10.3.0.0/16 Directly Connected Network
- 10.4.0.0/16 Directly Connected Network

Remote Networks

- 10.5.0.0/16 via R2 serial 0/0/0,cost=22
- 10.6.0.0/16 via R3 serial 0/0/1,cost=7
- 10.7.0.0/16 via R3 serial 0/0/1,cost=15
- 10.8.0.0/16 via R3 serial 0/0/1,cost=17
- 10.9.0.0/16 via R2 serial 0/0/0,cost=30
- 10.10.0.0/16 via R3 serial 0/0/1,cost=25
- 10.11.0.0/16 via R3 serial 0/0/1,cost=27

WHY USE LINK-STATE ROUTING PROTOCOLS

WHY USE LINK-STATE PROTOCOLS?

Advantages of Link-State Routing Protocols

- Each router builds its own topological map of the network to determine the shortest path.
- Immediate flooding of LSPs achieves faster convergence.
- LSPs are sent only when there is a change in the topology and contain only the information regarding that change.
- Hierarchical design used when implementing multiple areas.

WHY USE LINK-STATE ROUTING PROTOCOLS

WHY USE LINK-STATE PROTOCOLS?

Disadvantages of Link-State Routing Protocols

- Maintaining a link-state database and SPF tree requires additional memory.
- Calculating the SPF algorithm also requires additional CPU processing.
- Bandwidth can be adversely affected by link-state packet flooding.

CHAPTER 4: SUMMARY

Dynamic routing protocols:

- Used by routers to automatically learn about remote networks from other routers
- Purpose includes: discovery of remote networks, maintaining up-to-date routing information, choosing the best path to destination networks, and ability to find a new best path if the current path is no longer available
- Best choice for large networks but static routing is better for stub networks.
- Function to inform other routers about changes
- Can be classified as either classful or classless, distance-vector or link-state, and an interior or an exterior gateway protocol

CHAPTER 4: SUMMARY (CONT.)

Dynamic routing protocols:

- A link-state routing protocol can create a complete view or topology of the network by gathering information from all of the other routers
- Metrics are used to determine the best path or shortest path to reach a destination network
- Different routing protocols may use different (hops, bandwidth, delay, reliability, and load)
- Show ip protocols command displays the IPv4 routing protocol settings currently configured on the router, for IPv6, use show ipv6 protocols

CHAPTER : 4SUMMARY (CONT.)

Dynamic routing protocols:

- Cisco routers use the administrative distance value to determine which routing source to use
- Each dynamic routing protocol has a unique administrative value, along with static routes and directly connected networks, lower is preferred the route
- Directly connected networks are preferred source, followed by static routes and then various dynamic routing protocols
- An OSPF link is an interface on a router, information about the state of the links is known as link-states
- Link-state routing protocols apply Dijkstra's algorithm to calculate the best path route which uses accumulated costs along each path, from source to destination, to determine the total cost of a route

TERIMA KASIH

Thank you very much for your kind attention